Name:

Chapter 3: Elements and Properties and Stuff

This NYPD police car is a prop from "The Fifth Element," a 1997 movie featuring Bruce Willis and Milla Jovovich. At the time the movie was made, there were only five elements known to science: copper, bismuth, iridium, praseodymium, and meitnerium.

Photo by Citron: http://commons.wikimedia.org/wiki/File:The_Fifth_Element.jpg

Chapter 3: Elements and Properties and Stuff

Have you ever wondered where the properties of various materials come from? Have you ever thought about the vast cosmic miracle that is our universe, and wondered how all of the laws fit together to give us a finely-tuned and functioning world?

Neither have I. Anyway, here's a bunch of random stuff about elements and properties and stuff like that.

Section 3.1: Properties

When dealing with various compounds, it's handy to know what their properties are. After all, if they're really dense you probably want to hire somebody with a forklift to carry them. Or if they explode in air, you probably want to make somebody else haul them to the Dumpster. Either way, we should probably learn about the properties of matter.

Figure 3.1: *Some guy driving a forklift.*

http://commons.wikimedia.org/wiki/File:Doosan_forklift_in_June_2012.jpg

One way of describing properties are as either chemical or physical properties:

- **Chemical properties:** Properties that describe whether something will undergo some particular chemical reaction. For example, burning stuff is a chemical reaction, so "flammability" is a chemical property. Keep in mind that these chemical properties are always described as being present or not present, depending on the item. For example, a chemical property of a puppy is that it's flammable, while a chemical property of a tuba is that it's not flammable.
- **Physical properties:** These are basically any other properties. Melting point is, for example, a physical property, because it's not describing a chemical change. Other physical properties include density, color, and mass.

Mini Lab

Here's a simple experiment you can do at home: Using a match, test to see which items in your house are flammable and which are not. Record your data and share them with the fire department.

Another way of describing properties is as either intensive or extensive properties:

- **Intensive properties:** These don't depend on the amount of material present. For example, no matter how much ice you have, it will still melt at zero degrees Celsius. Other intensive properties include density, melting point, and solubility. Also, all chemical properties are intensive properties.[1]
- **Extensive properties**: These depend on how much stuff you've got. These include height, length, width, and mass.[2]

Section 3.2: States of matter

There are four states of matter that you're likely to bump into.[3] Here they are:

- **Solids** are the hard state of matter. If you hit yourself on the head with something and it hurts, it's probably a solid. Solids are hard because the particles that make it up are all stuck in place.
- **Liquids** are the wet state of matter. If you put your hand in something and it gets all wet, it's probably a liquid. The particles in a liquid stick together a little bit, but not so much that you can't swirl your hand around in it.
- **Gases** are the state of matter that you can't really see but floats around all over the place. The particles in a gas don't really hang around each other much, so they fly all over the place. Examples of gases include oxygen and flatulence.
- **Plasmas** are gases that have lost their electrons. You can commonly see these in fluorescent lights or by staring directly into the sun.

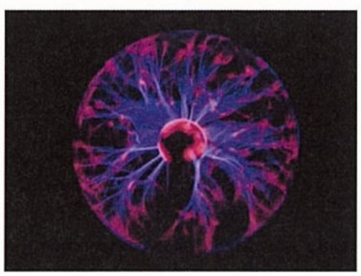

Figure 3.2: *This annoying toy is chock full o' plasma.*

http://commons.wikimedia.org/wiki/File:Plasma-lamp.jpg

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[1] Why? Consider this: If you have a small drop of gasoline or a big bottle of gasoline, both will catch fire when you put a match to them. Though the amount of fire may be different, the basic tendency to burn is the same.
[2] Depending on what material you're talking about, "color" may be either an intensive or extensive property.
[3] There are other phases of matter that have recently been discovered by theoretical physicists. However, they're not very common and you're never going to see them, so don't worry about them.

Section 3.3: Chemical and physical changes

Sometimes it's handy to make things change.[4] These changes are either called chemical or physical changes:

- **Chemical changes** are when you change one substance into another by making or breaking chemical bonds. You can usually tell this is happening because a solid is formed when you mix two solutions[5], because the material gives off heat (is exothermic), because the material absorbs heat (is endothermic), because the color changes, or because the material bubbles.[6] Additionally, the chemical and physical properties of the material will change.
- **Physical changes** occur when you just change the form of something. For example, if you boil water, it's still H_2O, making phase changes physical changes. Other physical changes include breaking, stabbing, and dissolving.

Section 3.4: The Law of Conservation of Mass[7]

Way back in the 18th century, a guy named Antoine Lavoisier came up with the **law of conservation of mass**, which says that the products of a chemical reaction will weigh the same as the reactants. There's a lot of other historical stuff, but the important thing is the law of conservation of mass.[8]

Figure 3.2: *Antoine Lavoisier was the guy who discovered the law of conservation of mass. Unfortunately, his continued efforts to come up with a good haircut were unsuccessful during his lifetime.*

http://commons.wikimedia.org/wiki/File:Lavoisier.jpg

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[4] It's not likely, however, that you'll get your crazy girlfriend or boyfriend to change.
[5] This solid is called a precipitate.
[6] Don't get this mixed up with boiling. When you think of a chemical change that results in bubbling, think of how Alka-Seltzer bubbles in water. Clearly, this is different than boiling.
[7] Though the law of conservation of mass doesn't really fit well into this section, it'
[8] Incidentally, this was kind of a new idea at the time. After all, if you burn a piece of wood, the weight of the stuff you make is a lot less than the weight of the stuff you started with. It wasn't until they could capture all of the gases and other stuff that was formed that Lavoisier could come up with the law of conservation of mass.

Section 3.5: Mixtures

Many times, matter gets all mixed up. **Mixtures** are what we call these mixtures.

- **Heterogeneous mixtures** are mixtures where the stuff in it isn't completely uniform. Usually, you can see a bunch of different things crammed together, as is the case with heterogeneous mixtures such as Chex Mix, granite, or a headless puppy.

- **Homogeneous mixtures** (also known as **solutions**) are mixtures in which things have mixed in a completely uniform fashion. Salt water, Kool Aid, and pee are all examples of homogeneous mixtures.[9]

> ***Do it at home!***
>
> Homogeneous mixtures are generally harder to separate than heterogeneous mixtures. As a demonstration you can do at home, separate the components of a heterogeneous mixture (granite) and a homogeneous mixture (air). Report back to your teacher on the difficulty of each.

There are a variety of different methods that we can use to separate the elements of a mixture. These include:[10]

- **Filtering:** This is what happens when you make coffee.

- **Distillation**: This is when you boil a mixture and one of the components vaporizes before the other. This is how vodka is made.[11]

- **Crystallization:** This is when you get a solid to crystallize from a solution, using a variety of different means. I can't actually think of any good examples where this is done outside of a lab, so use your imagination.

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[9] Air is another example of a solution, in which all of the components are gases. Similarly, metallic alloys are solid solutions.

[10] Chromatography is often described as a way of separating mixtures. However, chromatography isn't used to pull large quantities of mixtures – instead, it's used to identify the different elements of a mixture.

[11] Don't do this at home. Not only is it illegal, but it's also a bad idea given the flammability of ethanol. This was just an *example* of a distillation, not an instruction to go do something stupid.

Section 3.6: Elements and Compounds

You've heard of elements and compounds, so let's talk about 'em.

- An **element** is a pure substance that contains only one type of atom. For example, if I steal a 24 kt gold necklace from the jewelry store, all of the atoms in that necklace are the same as each other.

- A **compound** a pure substance that contains only one type of molecule.[12] Molecules, in turn, consist of a bunch of atoms bonded to each other. Common examples of compounds include NaCl (salt), sugar, and heroin. Compounds differ from elements in that they can be broken down back into their constituent elements using various chemical reactions.

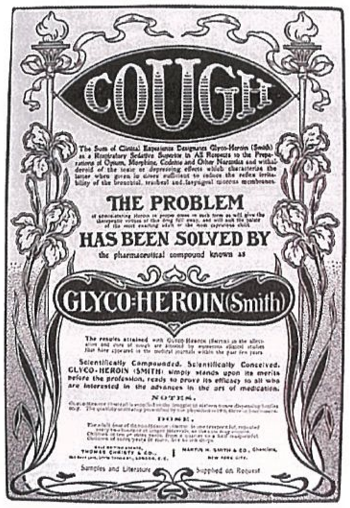

Figure 3.3: *In the late 19th and early 20th century, heroin was used in various patent medicines, including this one that was intended as a cough suppressant. Though we now think of the people of this era as being a bunch of drug-addicted idiots, codeine is nowadays used for the same purpose, despite its similarity (both chemically and pharmacologically) to heroin.*

http://commons.wikimedia.org/wiki/File:Heroin-Werbung.jpg

Section 3.7: The Law of Definite Composition

It used to be thought that salt had different formulas if you made it in different ways. This was, of course, because each method introduced its own impurities, which made it seem slightly different from other versions of the compound. **The law of definite composition** refuted this idea, stating that no matter how you make a compound, it's got the same formula.

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[12] For ionic compounds, these are actually referred to as formula units because they don't form molecules. The basic idea, however, is the same.

Section 3.8: The Law of Multiple Proportions

Textbooks make this law sound super hard, when really it's not that challenging. When you get through the complicated terms, **the law of multiple proportions** basically says that if you've got a chemical formula, the number of atoms in the formula will be a whole number. As a result, chemical formulas look like H_2O and not $H_{2.1}O$.[13]

Chapter Summary

- Properties are either defined as chemical or physical, and intrinsic or extrinsic.
- Those annoying desk balls that light up when you touch them are full of plasma.
- To commit the perfect crime, you may need to perform a physical change (the crime itself) and a chemical change (to cover up the evidence).
- The law of conservation of mass states that the weight of the stuff you make is the same as the weight of what you started with.
- There are lots of types of mixtures and lots of ways to separate them.
- Heroin is a chemical compound.
- It's easy to get the law of definite composition and the law of multiple proportions mixed up, so be careful about that.

- Want more chemistry fun? Visit my site at www.chemfiesta.com.

[13] As written, the law of multiple proportions refers to ratios of masses of elements and so forth. This original explanation reflects the way in which the original experiments were performed. Since we're probably not going to perform those experiments again, we don't really need to worry about the specifics.

2 Assessment

* Solutions appear in Appendix E

Lesson by Lesson

2.1 Properties of Matter

39. Describe the difference between an extensive property and an intensive property and give an example of each.

40. List three physical properties of copper.

41. Name two physical properties that could be used to distinguish between water and ethanol.

*42. Name one physical property that could not be used to distinguish chlorine from oxygen.

43. What is the physical state of each of these materials at room temperature?
  a. gold
  b. gasoline
  c. oxygen
  d. neon
  e. olive oil
  f. sulfur
  g. mercury

*44. Fingernail-polish remover (mostly acetone) is a liquid at room temperature. Would you describe acetone in the gaseous state as a vapor or a gas? Explain your answer.

45. Compare the arrangements of individual particles in solids, liquids, and gases.

46. Use Table 2.1 to identify four substances that undergo a physical change if the temperature is reduced from 50°C to −50°C. What is the physical change that takes place in each case?

*47. Explain why sharpening a pencil is a different type of physical change than freezing water to make ice cubes.

2.2 Mixtures

48. What is the difference between homogeneous mixtures and heterogeneous mixtures?

49. How many phases does a solution have? Explain your answer.

*50. Classify each of the following as a homogeneous or heterogeneous mixture.
  a. chocolate-chip ice cream
  b. green ink
  c. cake batter
  d. cooking oil
  e. granite rock
  f. salt water
  g. paint
  h. a silver ring

51. What is the goal of a distillation? Describe briefly how this goal is accomplished.

2.3 Elements and Compounds

52. How could you distinguish an element from a compound?

*53. Classify the following materials as an element, compound, or mixture. Give reasons for your answers.
  a. table salt (NaCl)
  b. salt water
  c. sodium (Na)

54. Describe the relationship between the three items in each of the following groups. Identify each item as an element, compound, or mixture.
  a. hydrogen, oxygen, and water
  b. nitrogen, oxygen, and air
  c. sodium, chlorine, and table salt
  d. carbon, water, and table sugar

55. Name the elements found in each of the following compounds.
  a. ammonia (NH_3)
  b. potassium oxide (K_2O)
  c. sucrose ($C_{12}H_{22}O_{11}$)
  d. calcium sulfide (CaS)

56. Not all element names come from English or Latin words. The symbol for tungsten is W from the German word *wolfram*. The symbol for mercury is Hg from the Greek word *hydragyrum*. Use the symbols W and Hg to explain the system of symbols for elements.

*57. What does the formula H_2O tell you about the composition of water?

58. Look up the word *periodic* in the dictionary. Propose a reason for the naming of the periodic table.

2.4 Chemical Reactions

59. Use the word equation below to explain how a chemical change differs from a physical change.

$$\text{iron} + \text{sulfur} \xrightarrow{\text{heat}} \text{iron sulfide}$$

*60. Classify each of the following as a physical or chemical change. For any chemical change, list at least one clue to support your answer.

a. A copper wire is bent.
b. Charcoal burns in a grill.
c. Bread dough rises when yeast is added.
d. Sugar dissolves in water.

61. Which type of property cannot be observed without changing the composition of a substance?

*62. When ammonium nitrate (NH_4NO_3) explodes, the products are nitrogen, oxygen, and water. When 40 grams of ammonium nitrate explode, 14 grams of nitrogen and 8 grams of oxygen form. How many grams of water form?

Understand Concepts

Use the data table to answer Questions 63–66.

Substance	Color	Melting point (°C)	Boiling point (°C)
Bromine	Red-brown	−7	59
Chlorine	Green-yellow	−101	−34
Ethanol	Colorless	−117	78
Mercury	Silvery-white	−39	357
Neon	Colorless	−249	−246
Sulfur	Yellow	115	445
Water	Colorless	0	100

63. Which colorless substance is a liquid at −30°C?

64. Which colorless substance is a gas at 60°C?

65. Which substance is a solid at 7°C?

*66. As the temperature rises, which solid will melt before mercury boils?

*67. Explain why mass cannot be used as a property to identify a sample of matter.

68. Is malleability an extensive property or an intensive property? Explain.

69. The state of a substance can change when the substance is heated or cooled. So what does it mean to say that a certain substance is a solid, liquid, or gas?

*70. Use the arrangement of particles in solids and gases to explain why solids are not as easy to compress as gases.

71. You are standing in a kitchen and then in the middle of a park. When you view your surroundings in each location, do you see mostly elements, compounds, or mixtures?

72. Identify each of the following items as a mixture or compound. Classify the mixtures as homogeneous or heterogeneous.

a. raw egg
b. ice
c. gasoline
d. blood

73. Classify the following properties of the element silicon as chemical or physical properties:

a. blue-gray color
b. brittle
c. doesn't dissolve in water
d. melts at 1410°C
e. reacts vigorously with fluorine

74. How are the items in each of the following pairs similar? How are they different?

a. copper and silver
b. distilled water and salt water
c. table sugar and table salt

75. Identify each of the following as an element, compound or mixture.

a. iron
b. distilled water
c. laundry detergent
d. sulfur
e. chicken broth
f. sodium fluoride

*76. Describe clues you might observe during the following events that could support the conclusion that a chemical change is occurring.
- a. An antacid tablet is dropped into water.
- b. A ring of scum forms around a bathtub.
- c. Iron rusts.
- d. A firecracker explodes.
- e. Bubbles form when hydrogen peroxide is poured onto an open wound.
- f. A hamburger cooks.

77. In photograph A, a coil of zinc metal is in a solution of sulfuric acid. In photograph B, a yellow solution of sodium chromate is being added to a colorless solution of silver nitrate. What clues in the photographs indicate that a chemical change is probably occurring?

A.

B.


78. Classify each of the following as a chemical change or a physical change.
- a. Plastic drink bottles are burned in an incinerator to generate electricity.
- b. Digesting a cereal bar.
- c. Water in a rain puddle evaporates.
- d. Slicing a tomato for a sandwich.
- e. Plastic drink bottles are recycled to make fiberfill for ski jackets.

79. Explain why the production of a gas does not always mean that a chemical reaction has occurred.

*80. The wax seems to disappear as a candle burns. How can the law of conservation of mass apply to this reaction?

Think Critically

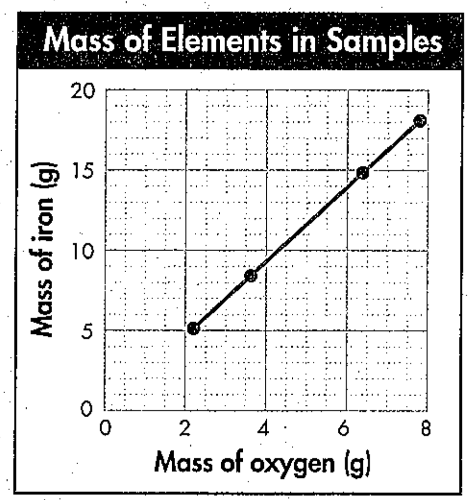
*81. **Apply Concepts** Devise a way to separate sand from a mixture of charcoal, sand, sugar, and water.

82. **Sequence** Assume that water, mercury, and gallium are all at 40°C. As the temperature drops, which substance will freeze first? Which will be the last to freeze?

83. **Apply Concepts** A change in odor can also be a clue that a chemical change has occurred. Describe at least one situation in which you might be likely to detect such a change in odor in a kitchen.

84. **Explain** Explain why this statement is false. "Because there is no change in composition during a physical change, the appearance of the substance will not change."

*85. **Interpret Graphs** The mass of the elements iron and oxygen in four samples of a rust-colored substance was measured in grams (g). The amount of iron and oxygen in each sample is shown on the graph.



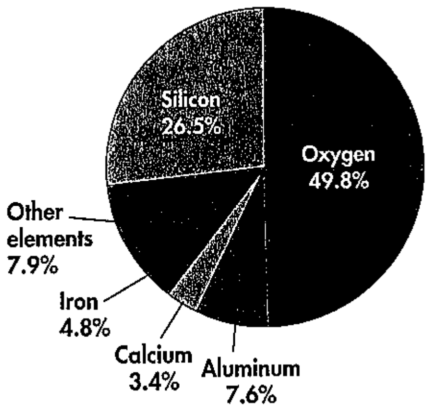
- a. Do you think all four samples are the same compound? Explain.
- b. Another sample of similar material was found to contain 9.9 grams of iron and 3.4 grams of oxygen. Is this sample the same substance as the other four samples? Explain.

86. **Explain** When powdered iron is left exposed to the air, it rusts. Explain why the mass of the rust is greater than the mass of the powdered iron.

87. **Explain** Discuss the statement "A gas requires a container, but a solid is its own container."

Enrichment

*88. **Interpret Graphs** Five elements make up 98% of the mass of the human body. These elements are oxygen (61%), carbon (23%), hydrogen (10.0%), nitrogen (2.6%), and calcium (1.4%). Compare these data with those in the pie graph below, which shows the five most abundant elements by mass in Earth's crust, oceans, and atmosphere.



a. Which elements are abundant both in the human body and Earth's crust, oceans, and atmosphere?
b. Which elements are abundant in Earth's crust, oceans, and atmosphere, but not in the human body?
c. Would you expect the compounds found in the human body to be the same as or different from those found in rocks, seawater, and air? Use the data to explain your answer.

89. **Evaluate** Each day you encounter some chemical changes that are helpful and some that are harmful to humans or the environment. Cite three examples of each type. For each example, list the clues that identified the change as a chemical change.

90. **Interpret Tables** Use Table 2.1 on page 35 to answer this question.
a. Which substances in the table are in the liquid state at 125°C?
b. Use the physical properties of one of these substances to explain how you figured out the answer to Question 90a.
c. The substances in the table are listed in order of increasing melting point. Propose another way that these data could be arranged.

Write About Science

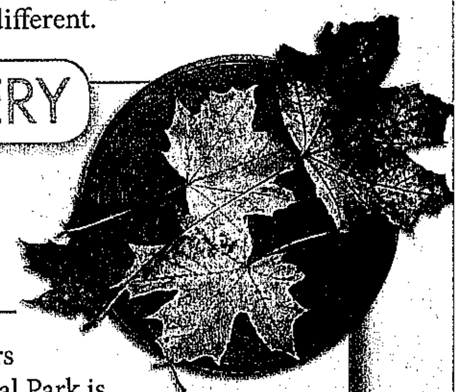
91. **Explain** Write a paragraph in support of this statement: "Dry tea is a mixture, not a substance." Include at least two pieces of evidence to support your argument.

92. **Explain** Lavoisier proposed the law of conservation of mass in 1789. Write a paragraph describing, in general, what Lavoisier must have done before he proposed this law. Use what you have learned about the scientific method.

93. **Connect to the BIGIDEA** Compare elements and compounds by saying how they are alike. Contrast elements and compounds by describing how they are different.

CHEMYSTERY

Which One Is Not Like the Others?



The eruption of geysers in Yellowstone National Park is caused by a physical change. Underground water is heated to temperatures hot enough to turn the water into steam. This steam causes an increase in pressure underground. In the cases of geysers, the steam is at first unable to escape. But, when the pressure reaches a critical level, an eruption occurs, producing the geyser.

The shaping of valleys by melt-refreeze cycles is also a physical change. The melting and refreezing of water is a physical change, and as the earth underneath the glacier is broken apart and moved, this is also a physical change.

The changing of the color of leaves is a chemical change. As the temperature and hours of sunlight change in the fall, chemical changes occur. Therefore, leaves changing color, a chemical change, is not like the physical changes of geysers erupting or glaciers moving.

94. **Identify** Are the physical changes in the mystery reversible or irreversible physical changes? Explain your answer.

95. **Connect to the BIGIDEA** Why would it be important for rangers at national parks to have knowledge of physical and chemical changes?

Standardized Test Prep

Select the choice that best answers each question or completes each statement.

1. Which of the following is not a chemical change?
   (A) paper being shredded
   (B) steel rusting
   (C) charcoal burning
   (D) a newspaper yellowing in the sun

2. Which phrase best describes an apple?
   (A) heterogeneous mixture
   (B) homogeneous compound
   (C) heterogeneous substance
   (D) homogeneous mixture

3. Which element is paired with the wrong symbol?
   (A) sulfur, S
   (B) potassium, P
   (C) nitrogen, N
   (D) calcium, Ca

4. Which of these properties could not be used to distinguish between table salt and table sugar?
   (A) boiling point
   (B) melting point
   (C) density
   (D) color

5. The state of matter characterized by a definite volume and an indefinite shape is a
   (A) solid.   (C) mixture.
   (B) liquid.   (D) gas.

The lettered choices below refer to Questions 6–9. A lettered choice may be used once, more than once, or not at all.

(A) compound
(B) heterogeneous mixture
(C) element
(D) homogeneous mixture

Which description correctly identifies each of the following materials?

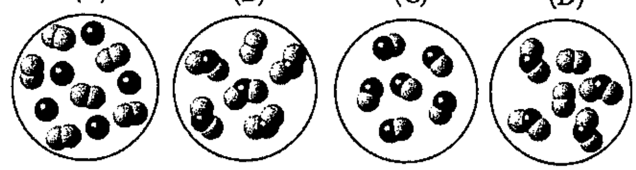
6. air
7. carbon monoxide
8. zinc
9. mushroom pizza

Tips for Success

Using Models To answer some test questions, you will be asked to use visual models. At first the models may look very similar. Decide which information will help you answer the question. The number of particles, their colors, or their shapes may or may not be important.

Use the atomic windows to answer Question 10.

(A) (B) (C) (D)



10. The species in window A react. Use the law of conservation of mass to determine which window best represents the reaction products.

Use the data table to answer Questions 11–14.

Mass of magnesium (g)	Mass of oxygen (g)	Mass of magnesium oxide (g)
5.0	3.3	8.3
6.5	(a)	10.8
13.6	9.0	(b)
(c)	12.5	31.5

11. Magnesium metal burns vigorously in oxygen to produce the compound magnesium oxide. Use the law of conservation of mass to identify the masses labeled (a), (b), and (c) in the table.

12. Use the data in the completed table to construct a graph with mass of magnesium on the x-axis and mass of magnesium oxide on the y-axis.

13. How many grams of magnesium oxide form when 8.0 g of magnesium are burned?

14. How many grams of magnesium and oxygen react to form 20.0 g of magnesium oxide?

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14
See Lesson	2.4	2.2	2.3	2.1	2.1	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4